VIRGINIA DIVISION OF GEOLOGY AND MINERAL RESOURCES

DIGITAL REPRINT OF GUIDE TO FOSSIL COLLECTING IN VIRGINIA

EUGENE K. RADER

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COMMONWEALTH OF VIRGINIA

DEPARTMENT OF CONSERVATION
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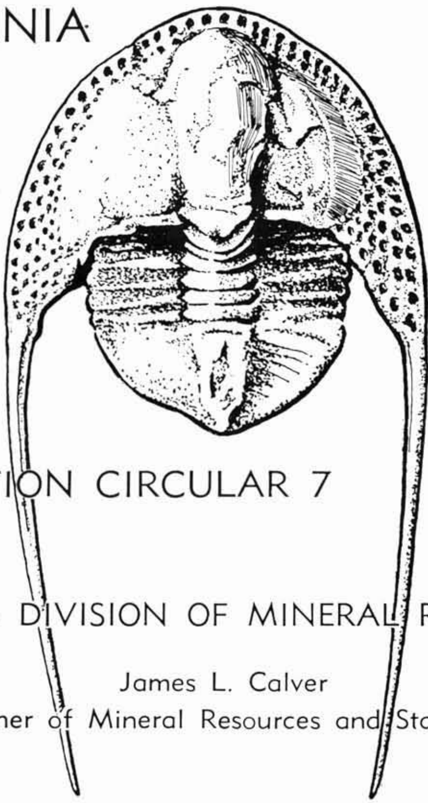
GUIDE TO FOSSIL COLLECTING IN VIRGINIA



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VIRGINIA DIVISION OF MINERAL RESOURCES

James L. Calver
Commissioner of Mineral Resources and State Geologist

CHARLOTTESVILLE, VIRGINIA
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Commonwealth of Virginia
Department of Purchases and Supply
Richmond
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GUIDE TO FOSSIL COLLECTING IN VIRGINIA

By

Eugene K. Rader

INTRODUCTION

Long before the first man appeared on earth, the earth's history was being recorded in the rocks. Prehistoric animals lived on the continents and in the great oceans that oscillated back and forth across the continents. When these animals died and were entombed in the sediments, that later became rock, a history of their environment was preserved. The remains or traces of these prehistoric animals are called fossils. That is, any trace of a once-living organism preserved before recorded history is a fossil.

Fossils are most common in marine sedimentary rocks that are formed by the deposition of sediments in a salt-water environment and by the compaction of the layers of sediment into rock layers or beds. For example, clay material derived from the erosion of the continents is deposited in the basin, and the weight of the overlying water and the continued deposition of clay material compresses the underlying layers of clay material to a shale. An enormous thickness of sedimentary rocks has accumulated since the beginning of the earth, especially in areas that were covered by seas most of the time. In a normal succession of beds the oldest layer is at the bottom and the youngest at the top.

Just as a millennium is divided into intervals of centuries, years, months and weeks, geologic time is also divided into time intervals called eons, eras, periods and epochs. The diversity and complexity of the organisms preserved in the rocks are of great importance to the geologist who wishes to assign relative ages to the rock layers. Table 1 shows the geologic time scale and the approximate time span for each period.

The earliest record of life on earth was made by single-celled organisms more than half a billion years ago in sediments of Precambrian

Table 1.—Geologic timetable and distribution of fossils.

ERA	PERIOD AND EPOCH	MILLIONS OF YEARS[2]	Diatoms	Radiolarians	Foraminiferas	Sponges	Stromatoporids	Corals	Bryozoans	Brachiopods	Gastropods	Nautiloids	Ammonites	Dibranchiates	Pelecypods	Ostracodes	Trilobites	Cystoids	Blastoids	Crinoids	Graptolites	Plants	Vertebrate bones, fish, tracks and trails	Dominant Forms of Life
CENOZOIC	QUATERNARY																							
	RECENT		xx	xx	xx	x		xx	x	x	xx	x		xx	xx	xx				x		xx	xx	
	PLEISTOCENE		xx	xx	xx	x		x	x	x	xx	x		xx	x	xx				x		xx	xx	
	TERTIARY	70																						mammals
	PLIOCENE		xx	xx	xx	x		x	x	x	xx	x		x	x	xx				x		x	x	
	MIOCENE		xx	xx	xx	x		xx	x	x	xx	x		x	xx	xx				x		x	xx	
	OLIGOCENE[1]																							
	EOCENE		xx	xx	xx	x		x	x	x	xx	x		x	x	xx				x		x	xx	
	PALEOCENE[1]																							
MESOZOIC	CRETACEOUS	135	x	x	x	x	x	x	x		x	x	x	x	x	xx				x		xx	xx	modern plants
	JURASSIC[1]	180																						reptiles
	TRIASSIC[3]	225																					x	ammonites and dinosaurs
PALEOZOIC	PERMIAN[1]	270																						
	PENNSYLVANIAN	310		x	x	x	x	x	x	x	x	x	x	x	x	x	x		xx	x		xx	x	seed ferns
	MISSISSIPPIAN	350		x	x	x	x	x	x	xx	x	x	x	x	x	x	x		xx	xx	x	xx	x	
	DEVONIAN	400		x	x	x	x	xx	xx	xx	x	x	xx		xx	xx	xx	x	x	xx	x	x	x	fishes
	SILURIAN	440		x	x	x	x	xx	xx	xx	x	x			x	xx	xx	x	x	x	x	x	x	corals
	ORDOVICIAN	500		x	x	x	xx	xx	xx	xx	xx	xx			xx	xx	xx	x	x	x	xx	x	x	straight cephalopods
	CAMBRIAN	600		x			x			x	x				x		xx				x	x	x	trilobites
	PRECAMBRIAN[4]																							

[1]Not present in Virginia
[2]Age at beginning of period
[3]Represented in Virginia as continental deposits
[4]No fossils have been reported from the Precambrian in Virginia

xFossils Reported
xxFossils Common

age. From this small beginning the organisms grew larger, more complex, and more varied, and after millions of years such creatures as dinosaurs evolved to dominate the earth. In the last 50 million or so years the enormous reptiles have given way to the mammals which today dominate the earth.

Fossils provide direct evidence of the plants and animals that lived during the past and information concerning how these organisms progressed and evolved through geologic time. When fossil assemblages and the rock enclosing them are studied in detail, certain conclusions may be made concerning their geologic age, the geographic relationships at the time of deposition, climate, temperature, and other environmental factors controlling the assemblages and rock types. A geologist studying rock sections from two widely separated areas tries to discover how the sections are similar or correlate. If the rocks are of the same geologic age, the fossils contained in them may be closely related. However, if the rocks are of different ages the fossils will probably be different.

TYPES OF PRESERVATION

Preservation of organic remains depends chiefly upon two requisites: (1) quick burial in a protective medium and (2) some type of hard parts. Any condition that is unfavorable to bacterial growth retards decay and is favorable to preservation. Burial in soft mud or volcanic ash, low temperature, very dry air, sea water, or a covering of tar or resin retard decomposition. Since quick burial is a prime requisite for fossilization, organisms that live in water have a better chance of being fossilized. Therefore, aquatic organisms are more common as fossils.

All organisms that die do not become fossils. Many organisms die and are not buried rapidly enough to prevent decomposition; others lack hard parts and are preserved only under unusual conditions. Many organisms that were originally preserved are destroyed by metamorphism and recrystallization.

Only in organisms from which bacteria is entirely excluded may the soft parts as well as the skeleton be preserved. The best known examples of preservation of soft parts are the remains of the mammoths and rhinoceroses that were buried in the frozen tundra of Siberia. The dry air of the desert, under certain conditions, may form natural mummies from organic remains. However, in the latter case only parts of the soft tissues are preserved. Preservation of this type is rare.

The composition of the hard parts of organisms varies from one group to another. Calcium carbonate (either calcite or aragonite), calcium phosphate, silica, complex organic compounds, or combinations of these are the common substances used by the organisms to build their hard parts. These mineral substances generally are not chemically pure but contain trace amounts of other elements, such as magnesium, strontium, iron and sulfur. Some fossils are preserved essentially without change except for the removal of the less stable organic matter (Plate 1, figure 2). Examples of shells that retain their original microstructure are abundant from the younger portion of the geologic column. Fossils of this type are abundant in the unconsolidated sands and clays of the Virginia Coastal Plain.

Many fossils show varying degrees of alteration of their hard parts. These alterations affect the physical structure, chemical composition, or both. Organisms that have hard parts composed of complex organic compounds are commonly preserved as thin carbon films (Plate 1, figure 1). Solution and other chemical action under water acts to decrease the volatile constituents of the tissues, thus leaving the carbon. Graptolites, arthropods, fish, and plants are commonly preserved in this manner.

Permineralization or petrifaction is the process by which porous materials, in this case shells and bones, are made more dense by the addition of mineral substances. In some cases the mineral substance is chemically the same as the shell or bone that it alters. Commonly, however, the infiltrating material differs from the composition of the fossil. Under suitable conditions the solution of the hard part, coupled with the simultaneous deposition of some other substance in the void, leads to replacement. Some of the most striking fossils of this type are those replaced by pyrite. These fossils are common in the Devonian black shales in Virginia.

During and after burial sedimentary material is commonly packed closely around the hard parts of the organism. The impression of the external surface of the skeleton, which is formed in the adjoining rock, is called an external mold (Plate 1, figure 4). The impression, if it reveals the form and markings of the inner surface, is called an internal mold. Commonly the skeletal material is removed by solution, leaving a void. If this void is filled by mineral matter, the result is called a cast.

Many animals, especially amphibians and reptiles, made tracks and trails with their feet, tails, and other portions of their bodies. These tracks and trails are common in certain localities. Less common are the impressions made by the soft-bodied jellyfish and starfish. Worm tubes and burrows are common but not readily recognized. Many fossil pelecypods have a small round hole near their beak (Plate 1, figure 3). This hole was drilled by a gastropod in search of food, much as the modern oyster bore attacks an oyster.

WHERE ARE FOSSILS FOUND?

Gullies, creeks, and river bluffs formed by the erosion of the soil are good places to look for bedrock exposures and fossils. Man also does his part to expose bedrock. Quarries, mines, pits, railroad and highway cuts, and excavations for canals, dams, and foundations generally present good exposures of rock in which the fossil collector or paleontologist can look for fossils. In many exposures excellent fossils that are impossible to remove will be found. If this is the case, do not spoil the fossil; others may wish to see it. At a later date weathering processes may remove some of the soft rock so that the fossil can be easily removed. Fossils are common in rocks of Paleozoic, Mesozoic, and Cenozoic ages. Refer to Table 1 and geologic map in pocket for the groups of rocks in which the various fossils may be found.

In most cases it will be necessary to cross private land to get to the rock exposures. BEFORE COLLECTING, OBTAIN PERMISSION FROM THE PROPERTY OWNER.

EQUIPMENT AND PREPARATION

Very little equipment other than sharp eyes and patience is needed to collect fossils. A brick layer's hammer, a few cold chisels, a haversack, newspaper, tissue paper, labels, a 10X hand lens, and a notebook are all that are required to equip the collector.

Generally fossils brought in from the field have bits of rock and dirt clinging to them and obscuring their detail. Washing with a detergent and vegetable brush usually will remove the dirt from the specimens. Excess rock can be removed with hammer and chisels, large chisels for coarser work and smaller ones for finer detail. Mounted needles should be used for the finest detail or for fragile specimens.

If a specimen is broken in the field or during preparation, it can be repaired with household cement. Fragile specimens or specimens with a weathered crumbly surface should be covered with a thin coat of clear nail polish for protection. Fragile or small specimens may be backed with or mounted on plaster of Paris or liquid plastic for easier handling. If the fossil is preserved as a mold, a cast of it is desirable to show what the fossil looked like in life. Liquid latex, which is available at any art shop, is satisfactory and dries readily.

CLASSIFICATION AND IDENTIFICATION

The modern classification system was first proposed by Carl Linne, a Swedish naturalist, in 1758. This classification groups related organisms together. Below are four examples of the Linnian system of classification.

Division	Animal and Plant			
	MAN	CARDINAL	OYSTER	DOGWOOD
Kingdom	Animalia	Animalia	Animalia	Plantae
Phylum	Chordata	Chordata	Mollusca	Spermatophyta
Class	Mammalia	Aves	Pelecypoda	Dicotyledoneae
Order	Primates	Passeres	Anisomyaria	
Family	Hominidae	Fringillidae	Ostreidae	Cornaceae
Genus	*Homo*	*Richmondena*	*Ostrea*	*Cornus*
Species	*sapiens*	*cardinalis*	*virginica*	*florida*

The name of any individual organism is a combination of the generic and specific names, i. e. *Homo sapiens*, *Ostrea virginica*, *Richmondena cardinalis*, and *Cornus florida*.

Names for fossils are derived either directly from Latin or Greek, or have Latin or Greek endings. These names may be altered as more specimens are collected and studied in greater detail. If an original name has been changed, the original author's name, which follows the species name, is placed in parentheses, i. e. *Astraeospongia meniscus* (Roemer).

There are several ways of identifying fossils. The simplest is to have an expert do it. This may be a good way at first. Later, when you wish to identify the specimen yourself, comparison with pictures in books and the descriptions that usually accompany them is the best method. A nearly complete specimen is necessary for the identification of small or simple fossils, but larger or more complex fossils may be identified from a fragment.

Fossils have little value if they are not accompanied by a detailed description of the locality from which they were collected. This will enable other people to return to the locality and make collections. Your name and the date of collection are also important. The name of the geological formation from which the fossil was collected, if known, is also useful.

KINGDOM PROTISTA

The minute, single-celled organisms that belong to the kingdom Protista lack a definite cellular arrangement. This kingdom includes single-celled organisms previously grouped with the plants in the phylum Thallophyta and those previously grouped with the animals in the phylum Protozoa, as well as several problematical groups.

PHYLUM CHRYSOPHYTA

Class Diatomaceae

(Plate 2, figures 1-8)

Diatoms are one-celled organisms that secrete a siliceous bivalve shell; they are found in both fresh-water and marine environments. The bivalve shell fits together like a shoe box. Diatoms range in size from 100 to 1000 microns. The shape of the shell ranges from spherical, subspherical, and hemispherical to cylindrical and spindle-shaped. Generally the spherical shape is indicative of marine environments; whereas most non-marine diatoms are elongate. These microscopic organisms are extremely abundant in modern seas, and their shells accumulate on the bottom as diatomaceous ooze. Indurated ancient diatomaceous oozes are called diatomite and may form extensive deposits. In Virginia, diatomite occurs in a few Coastal Plain localities.

PHYLUM PROTOZOA

Class ~~Actinopoda~~

(Plate 2, figures 9-13)

Subclass Radiolaria—Radiolarians are microscopic marine organisms that secrete a siliceous skeleton. Under the microscope the skeletons appear as globs or pyramids of glass with numerous holes and highly ornate spines. The skeletons range in size from a few microns to nearly 1 millimeter. The shape varies, but for the most part they are spherical or pyramidal. In Virginia radiolarians most commonly occur in the sediments of the Coastal Plain.

Class Rhizopoda

(Plate 3, figures 1-21)

Subclass Foraminifera—Foraminifera are microscopic, mainly marine organisms that secrete a shell, or test, of calcium carbonate or have a shell of tiny sand grains cemented with silica. "Forams" range in size from less than 1 millimeter to more than 100 millimeters. The shells are constructed of numerous chambers arranged in a variety of shapes. These tiny organisms are abundant in modern seas, and their shells form extensive areas of foraminiferal ooze on the sea floor. Ancient deposits of this ooze, that are now limestone, are quarried for use as building stones in the Midwestern States and in the Mediterranean area of Europe and Africa. "Foram" shells are present in most of the Coastal Plain formations, although a high-powered hand lens or microscope is necessary to find them.

KINGDOM ANIMALIA

Organisms belonging to the animal kingdom are multicellular and cannot manufacture their own food; they must depend either directly or indirectly on plant material for sustenance. The chief characteristics having significance in classification are: (1) complexity of body construction; (2) type of body symmetry; (3) presence or absence of a body cavity; (4) presence or absence of an anus; (5) segmentation of the body, or lack of it; and (6) nature of circulatory, respiratory, excretory, and nervous systems.

PHYLUM PORIFERA

(Plate 4, figures 1-3)

Porifera, or sponges, live attached to the bottom in salt or fresh water. Fossil sponges are not like the soft, pliable sponges with which most people are familiar, but, instead, have a hard skeleton of calcium carbonate, silica, or spongin spicules. The spicules composing the skeleton have a variety of shapes such as rods, clubs, disks, and others too complex to describe. They may be preserved individually or in groups. Fossilized sponges are not common in Virginia; however, a few specimens have been reported from the Paleozoic rocks of the Valley and Ridge province, and spicules are found in the Coastal Plain sediments.

PHYLUM COELENTERATA

The coelenterates are the most primitive organisms with a body cavity. That is, a space between the body wall and the lining of the digestive cavity. The body cavity is filled with fluid that contains the various substances which nourish the body cells. This phylum includes the hydroids, corals, jellyfish, and two extinct groups, the conularids and stromatoporids. Only the stromatoporids and corals are important as fossils.

Class Hydrozoa

(Plate 4, figure 4)

The stromatoporids are an extinct group of coral-like animals that built incrusting or massive, relatively dense, calcareous, laminated deposits which tend to split parallel to the laminations. Some colonies attained a thickness of 3 feet and a width exceeding 6 feet. The calcium carbonate skeletal layers are perforated by minute holes. Stromatoporids are common in limestones of Ordovician age.

Class Anthozoa

(Plate 4, figures 5, 6; Plate 5, figures 1-11)

This class includes the corals and sea anemones. Only the corals are important as fossils. The organisms, or polyps, secrete a stony skeleton, or coral, that is divided by radial partitions and horizontal platforms on which the polyp lives. Corals are divided into two general groups, colonial and solitary. The colonial corals live in colonies that are composed of hundreds of individuals attached to each other by their outer skeletal walls. This is the group that forms extensive reefs, some of which are hundreds of miles long. The skeletons of solitary polyps are horn- or tube-shaped with a depression at the top in which the animal lived. These corals are referred to as cup or horn corals. Colonial corals may be collected from the Tertiary sediments. Both solitary and colonial forms are present in the rocks of Ordovician, Silurian, and Devonian ages.

PHYLUM BRYOZOA

(Plate 6, figures 1-9)

Bryozoans are colonial organisms that secrete a stony skeleton of calcium carbonate. The skeleton is perforated with tiny holes, each of which was the home of a minute animal. The colonies are generally small, approximately 7 to 8 inches in length or diameter, although some types are extremely large (2 to 3 feet). Large bryozoans are rare in Virginia. Colonies live attached to the sea floor, to stones, or to other animals. Bryozoans are similar to corals but the tubes secreted by the individuals are smaller. Colonies grow in a variety of shapes and patterns: mound-shaped, lacy, tree-shaped, or screw-shaped. Bryozoans are most abundant in the Paleozoic rocks in the Valley and Ridge province.

PHYLUM BRACHIOPODA

(Plate 7, figures 1-20; Plate 8, figures 1, 2)

The brachiopods, or lamp-shells, secrete a bivalved shell of calcium carbonate, tri-calcium phosphate, or chitin (a complex organic substance similar to fingernails). The two valves that enclose the soft parts of the animal are dissimilar and are hinged together at one end. One valve usually rides over the other at the hinge margin to form a beak. Some forms have a depression called a sulcus in the pedicle valve which corresponds to a fold in the brachial valve. All brachiopods are marine, and most are attached to the ocean bottom by a fleshy stalk called a pedicle, which grows out through a hole near the beak of the shell.

Brachiopods are not common in oceans today, but in the past they were abundant, sometimes forming large shell banks. The best place to collect brachiopods in Virginia is from rocks of Paleozoic age.

PHYLUM MOLLUSCA

The phylum Mollusca includes the clams, snails, squids, octopuses, pearly nautiluses, and related extinct forms. Mollusks live in salt water, in fresh water, and on land. The mollusks have a soft body enclosed by a fleshy mantle which is modified ventrally into a foot for locomotion. Mollusks are commonly enclosed in a limy shell. This phylum includes five classes, three of which are important as fossils: the Gastropoda (snail), the Cephalopoda (pearly nautilus), and the Pelecypoda (clam).

Class Gastropoda

(Plate 8, figures 3-11)

The gastropod, or snail, carries its shell on its back and retreats into the shell whenever disturbed. Many forms have a horny or limy lid (operculum) which may be closed when the animal retreats into the shell. The common snail is coiled, either in one plane or spiraled. Gastropods are found in the sea, in fresh water, and on land. Fossil snails may be collected from Ordovician, Devonian, and Tertiary rocks.

Class Cephalopoda

(Plate 8, figures 12, 13; Plate 9, figures 1-4; Plate 10, figure 1)

The class Cephalopoda includes squids, devilfish, octopuses, and allied forms that are not common in the seas today. Paleozoic and Mesozoic seas abounded with certain shelled cephalopods that are now extinct. The pearly nautilus is the only species remaining of the shelled cephalopods. Many cephalopods have a coiled shell, much like a snail, that is divided into chambers by partitions called septa. The septa are pierced by a hole through which a tube-like organ, the siphuncle, passes. Cephalopods are exclusively marine.

Subclass Nautiloidea—Nautiloids are distinguished from other cephalopods by the straight character of their sutures. A suture is the trace of the junction of a septum and the shell wall. The animals belonging to this group live inside a compartmented shell that is either straight or coiled. Rocks of Ordovician age provide the best collecting for nautiloids.

Subclass Ammonoidea—The ammonites have a straight or coiled shell much like the nautiloids, except that the sutures are very complex. These organisms appeared early in Devonian time and died out before the end of Cretaceous time. Very few ammonites are reported from Virginia.

Subclass Dibranchiata—The Dibranchiata have an internal skeleton or lack a skeleton entirely. Squids, octopuses, cuttle fish, and belemnoids, an extinct form, belong to this subclass. The skeleton or shell inside the body is cigar-shaped. Fossilized members of this subclass are not common in Virginia; however a few belemnoids have been found.

Class Pelecypoda

(Plate 10, figures 2-9; Plate 11, figures 1-6)

The class Pelecypoda includes clams, oysters, scallops, and their relatives. The body is enclosed by two limy valves, or shells, that vary in shape from round to oblong, and some have one or two wing-like projections along the hingeline. The valves are closed by one or two large adductor muscles and held closed by interlocking teeth along the hingeline. The area of attachment of the adductor muscles leaves large scars that are important in classification. Pelecypods are for the most part marine, although a few live in fresh water. Most pelecypods crawl along the bottom using their fleshy foot for locomotion. A few types, such as the scallop, swim by clapping their valves open and shut.

Some live attached to the bottom by a fleshy stalk, and others, such as the oyster, attached to solid objects. The best collecting is from sediments of Tertiary age.

PHYLUM ARTHROPODA

The members of the phylum Arthropoda have jointed appendages and an external skeleton of chitin, which in some types is strengthened by calcium carbonate. The more familiar arthropods are the insects, spiders, lobsters, and crabs; less familiar are the scorpions, barnacles, ostracodes, and extinct groups such as the trilobites and eurypterids. This phylum consists of many classes, of which two are important as fossils.

Class Crustacea

(Plate 12, figures 1-8)

The class Crustacea includes the lobsters, crabs, crayfish, ostracodes, and their relatives; most crustaceans are marine. However, a few genera live in fresh water, and some crabs live on land. Fossil crustaceans, except for ostracodes, are not abundant in the rocks of Virginia.

Subclass Ostracoda—Ostracodes are one of the oddest of the crustaceans. They are microscopic, bivalved organisms that resemble a clam when the valves are closed. But when the live animal is examined closely, the jointed appendages characteristic of the arthropod group will be apparent. Ostracodes range in size from 0.5 millimeter to 1 centimeter. Many of the Paleozoic forms are highly ornamented, but the more recent forms are smooth and bean shaped. The majority of the families are marine, but a few live in fresh water. The best collecting is in the indurated or partly indurated sand and clay of Tertiary age. Some rocks of Ordovician, Silurian, and Devonian age contain an abundance of molds and casts.

Class Trilobita

(Plate 12, figures 9-21)

The trilobites are an extinct group of Arthropoda. They can be easily recognized by the two grooves that run from head to tail and divide the body into three distinct areas or lobes. This trilobation may be obscure on the head (cephalon) and tail (pygidium) of some species, but is always clear on the mid-section (thorax). The trilobites are exclusively marine and are abundant in limestones and shales of Ordovician, Silurian, and Devonian age.

PHYLUM ECHINODERMATA

The phylum Echinodermata includes starfish, sea urchins, sea lilies, and their less familiar relatives, cystoids and blastoids. All echinoderms have a five-fold radial symmetry; that is, they have a pattern of five rays or five (or multiples of five) arms around a body. They may live attached directly to the bottom, or attached by a stem, or they may be free moving. Echinoderms are exclusively marine. Only three classes will be discussed: Cystoidea, Blastoidea, and Crinoidea. The first two are extinct.

Class Cystoidea
(Plate 13, figures 1, 2)

Cystoids are primitive stemmed echinoderms with a spherical or sac-like body outline. The skeleton is composed of irregularly arranged plates with arms, or brachioles, for food gathering. The arms are rarely preserved as fossils. These extinct echinoderms are rare in the rocks of Virginia.

Class Blastoidea
(Plate 13, figures 3-9)

The blastoids have a pronounced five-fold symmetry and resemble a rose bud. The skeleton is composed of 13 plates arranged in three circlets. This organism, like the cystoid, has brachioles, but the blastoids have many more. Blastoids are common in limestones of Mississippian age.

Class Crinoidea
(Plate 13, figures 10-15)

Most crinoids, or sea lilies, are anchored to the bottom by a stem, although a few are free-swimming or floating forms. The skeleton, or cup, is composed of plates which usually scatter after the animal dies. The cup has five arms that may branch several times and are much longer than the cup. The stem is composed of interlocking plates stacked one on top of the other. A complete fossil specimen is rare, but numerous pieces of stems and plates have been found in the Ordovician, Silurian, Devonian, and Mississippian limestones of Virginia.

PHYLUM PROTOCHORDATA

The organisms of this phylum have a notochord, or rudimentary spinal cord, during part of their life history. These animals are intermediate between the invertebrates, which have no spinal cord, and the vertebrates, which have a spinal cord.

Class Graptolithina

(Plate 13, figures 16, 17)

This extinct group of colonial animals is abundant in some black shales and limestones. The animals lived in tiny chitinous cups arranged along a slender stem. In some forms the stem was attached to a float, and in others several stems might be attached together. Most graptolites floated free in the seas and were widely scattered. Fossilized graptolites look like black lines with sawtooth edges. They are common in the Ordovician shales of Virginia.

PHYLUM CHORDATA

(Plate 14, figures 1-7)

Animals with a backbone are called vertebrates and belong to the phylum Chordata. The vertebrates include reptiles, amphibians, fish, birds, and mammals. Few vertebrate fossils have been reported from Virginia. Fish scales have been reported from the Devonian rocks, and excellent fossil fish have been found in the Triassic rocks. Tracks of reptiles, amphibians, and mammals are also present in the Triassic. Whale bones and shark teeth have been found in the Tertiary sediments. Shark teeth are the only common vertebrate fossils found in Virginia.

KINGDOM PLANTAE

(Plate 14, figures 8, 9; Plate 15, figures 1-5)

Plant fossils are abundant in the coal beds and associated shales of Mississippian and Pennsylvanian age in southwestern Virginia. Ferns are the most abundant fossil plant although others are found. *Lepidodendron*, the scale tree, and *Sigillaria*, the jointed tree, are common in some areas. Fossilized plants are also reported from the Triassic coal basins in the Richmond area. Several collecting areas for plant fossils of Cretaceous age are known in Virginia.

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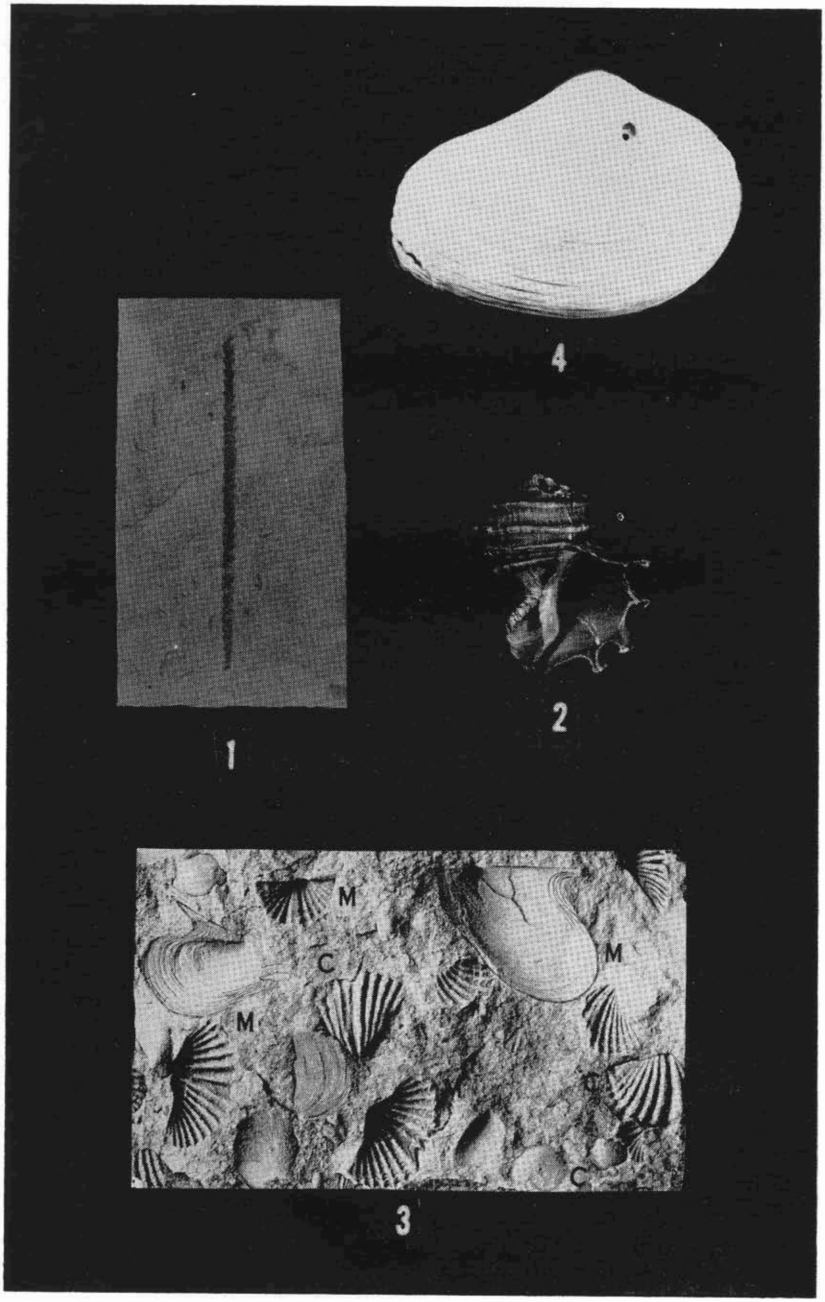
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EXPLANATION OF PLATE 1

Modes of Preservation

Figure

1. Carbonized graptolite.
2. Unaltered hard parts of a gastropod.[2]
3. Molds (m) and casts (c) of brachiopods (small, ribbed specimens) and pelecypods (large specimens).[1]
4. Pelecypod shell with a bore hole made by a gastropod.[2]

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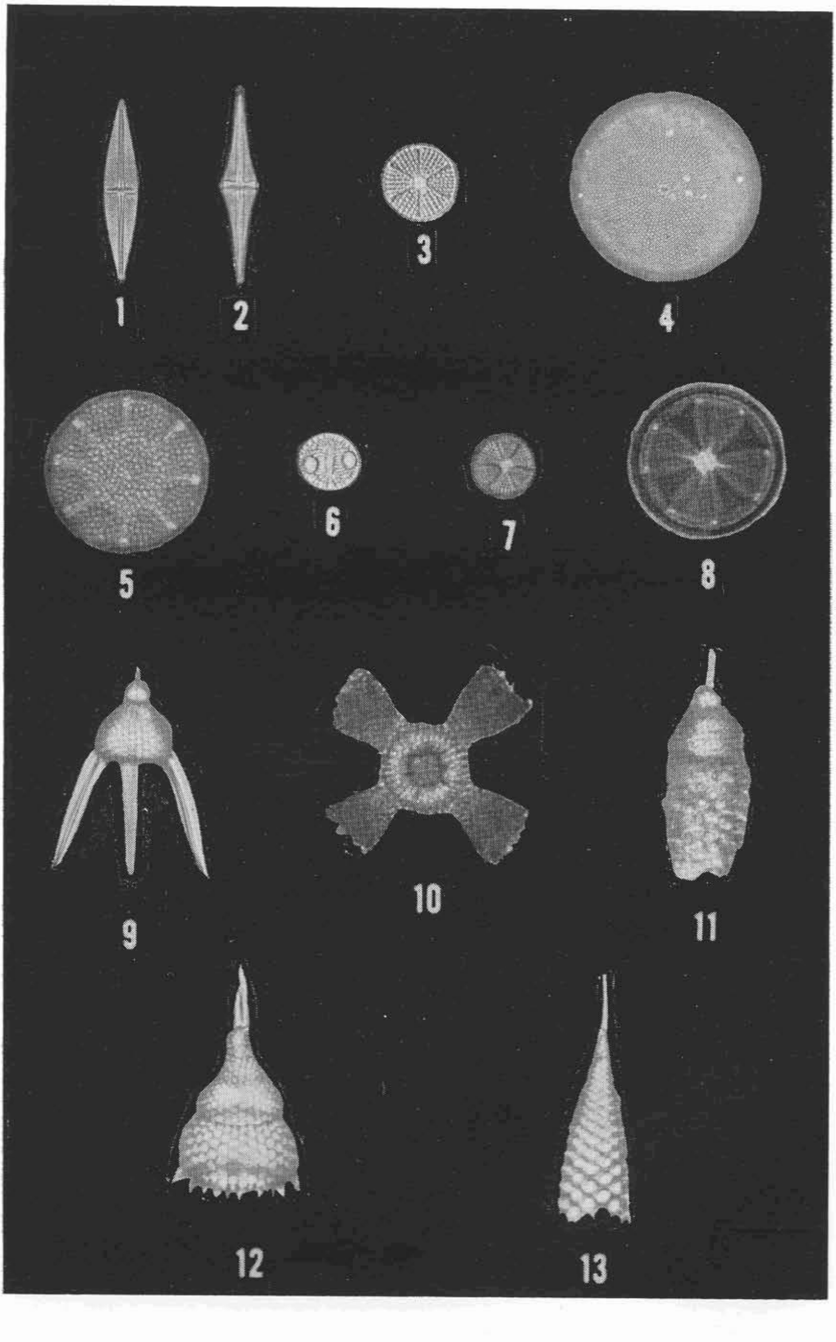
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EXPLANATION OF PLATE 2

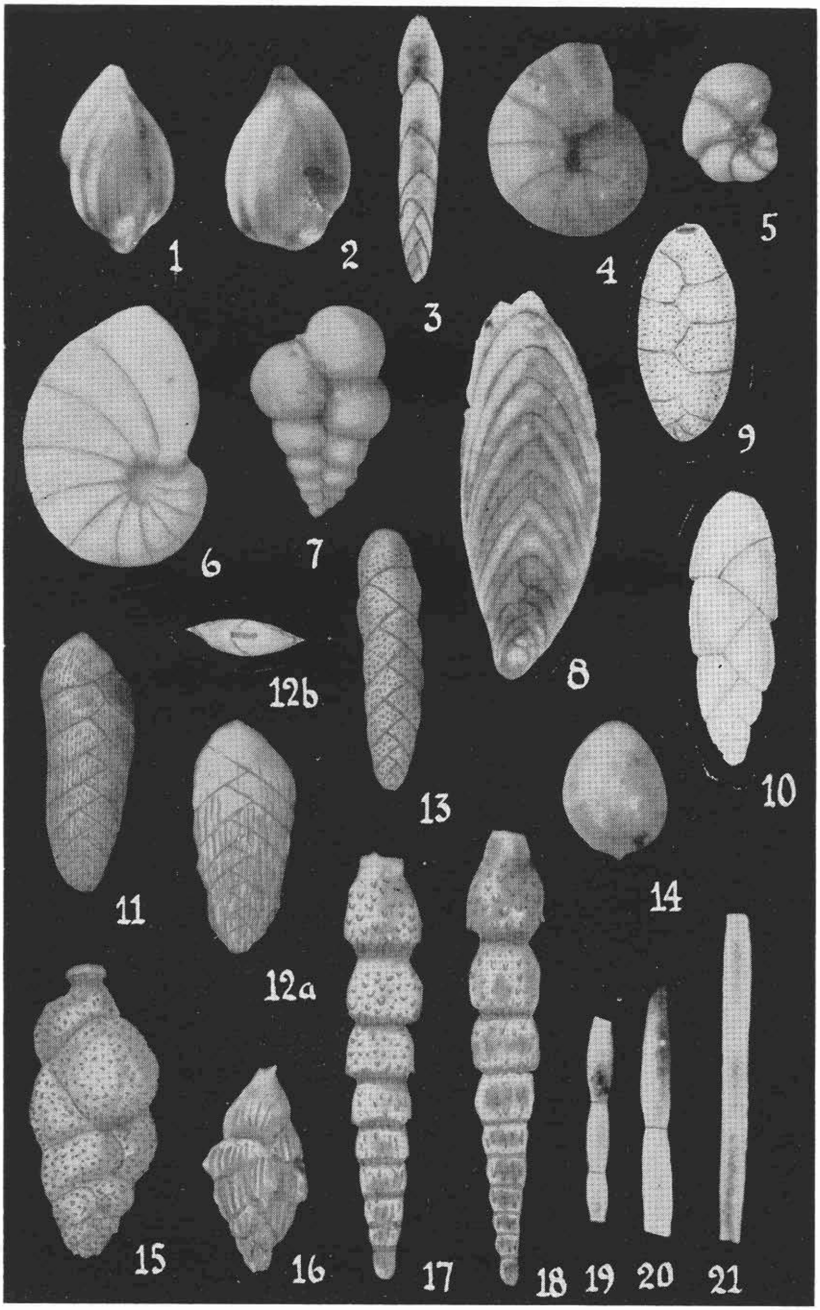
Diatoms

Figure

1. *Pinnularia* sp. A.
   X 100. Recent age.
2. *Pinnularia* sp. B.
   X 100. Recent age.
3. *Actinoptychus* sp. A.
   X 100. Recent age.
4. *Grammatophora* sp.
   X 100. Recent age.
5. *Actinoptychus* sp. B.
   X 100. Recent age.
6. *Actinoptychus?* sp. C.
   X 100. Recent age.
7. *Actinoptychus* sp. D.
   X 100. Recent age.
8. *Actinoptychus* sp. E.
   X 100. Recent age.

Radiolarians

9. *Podocyrtis* sp.
   X 100. Recent age.
10. *Hagiastrum* sp.
    X 100. Recent age.
11. *Cornutella* sp. A.
    X 100. Recent age.
12. *Anthocyrtidium* sp.
    X 100. Recent age.
13. *Cornutella* sp. B.
    X 100. Recent age.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EXPLANATION OF PLATE 3

Foraminifera[3]

Figure

1, 2. *Sigmoidella plummerae* Cushman and Ozawa. X 27. Tertiary age.

3. *Polymorphinella gracilis* Cushman and Cederstrom. X 42. Tertiary age.

4. *Nonion planatum* Cushman and Thomas. X 62. Tertiary age.

5. *Nonion danvillensis* Howe and Wallace. X 62. Tertiary age.

6. *Nonionella hantkeni* (Cushman and Applin), var. *spissa* Cushman. X 62. Teritary age.

7. *Gumbelina cubensis* Palmer, var. *heterostoma* Bermudez. X 100. Tertiary age.

8. *Plectofrondicularia virginiana* Cushman and Cederstrom. X 42. Tertiary age.

9. *Virgulina minutissima* Cushman. X 120. Tertiary age.

10. *Virgulina recta* Cushman, var. *howei* Cushman. X 120. Tertiary age.

11. *Bolivina gardnerae* Cushman, var. *lineata* Cushman and Cederstrom. X 100. Tertiary age.

12. *Bolivina virginiana* Cushman and Cederstrom. a, front view; b, apertural view; X 100. Tertiary age.

13. *Loxostomum longiforme* Cushman and Cederstrom. X 100. Tertiary age.

14. *Entosolenia* cf. *apiculata* (Reuss). X 100. Tertiary age.

15. *Uvigerina elongata* Cole. X 100. Tertiary age.

16. *Angulogerina danvillensis* Howe and Wallace. X 62. Tertiary age.

17, 18. *Ellipsonodosaria atlantisae* Cushman, var. *hispidula* Cushman. X 100. Tertiary age.

19–21. *Ellipsonodosaria* cf. *longiscata* (d'Orbigny). X 42. Tertiary age.

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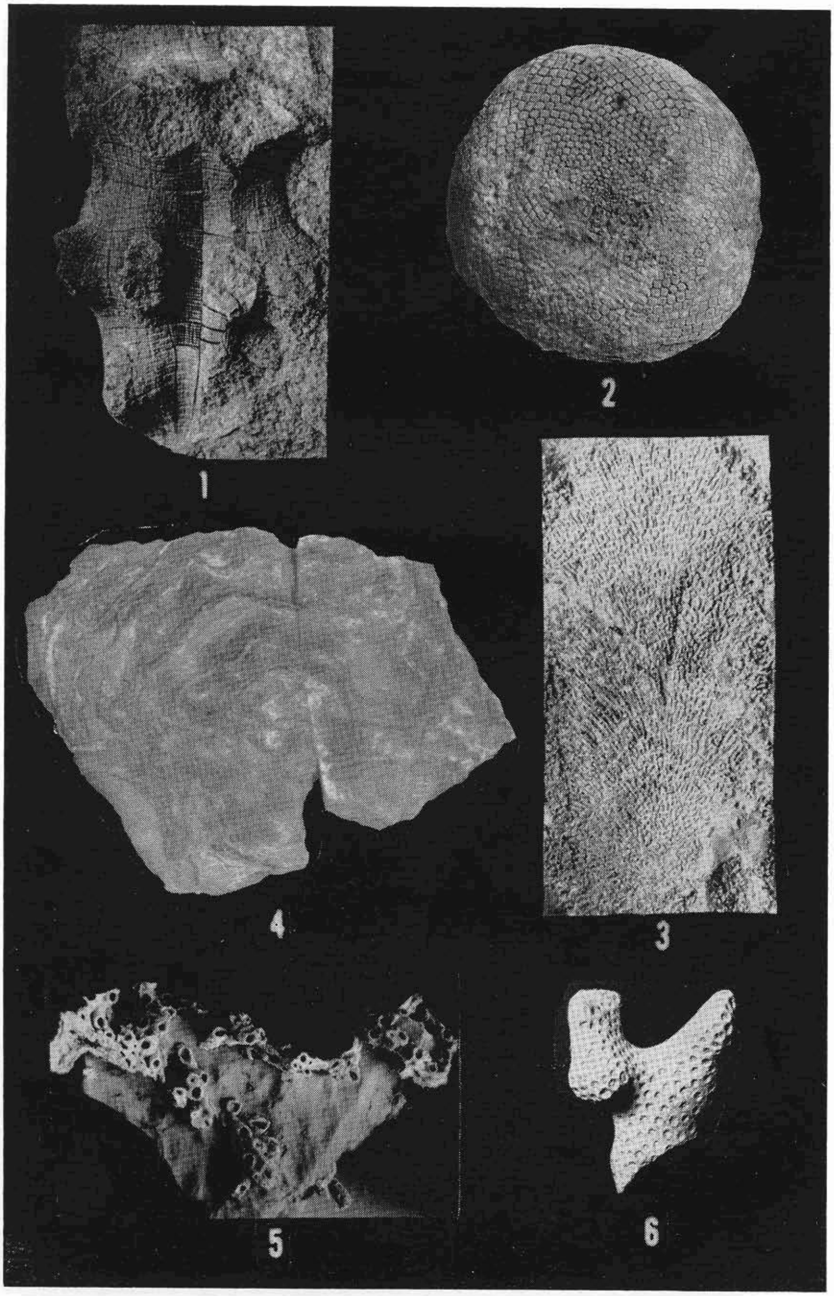
[3] Cushman, J. A., and Cederstrom, D. J., 1945, An upper Eocene foraminiferal fauna from deep wells in York County, Virginia: Virginia Geological Survey Bull. 67, p. 50, pl. 4.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EXPLANATION OF PLATE 4

Sponges

Figure

1. *Hydnoceras tuberosum* Conrad.
   Part of a cast of an external mold, X 1. Devonian age.[1]

2. *Receptaculites* sp.
   Top view of specimen showing ends and arrangement of pillars, X $\frac{3}{4}$. Ordovician age.[1]

3. *Dystactospongia* sp.
   Part of an impression of a sponge, X $\frac{3}{4}$. Ordovician age.[1]

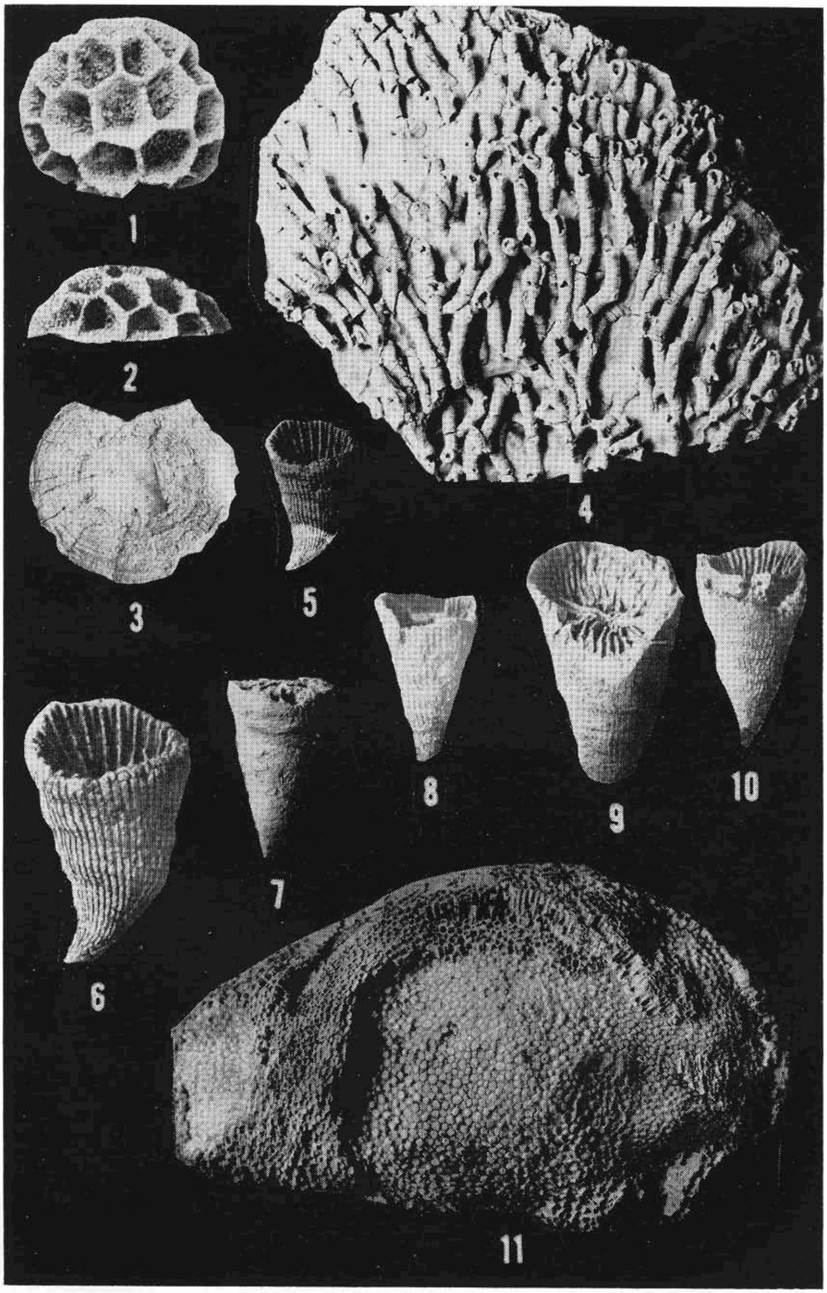
Stromatoporids

4. *Stromatocerium* cf. *rugosum.*
   X $\frac{1}{2}$. Ordovician age.

Corals

5. *Ceratopora* sp.
   Colony, X 1. Devonian age.[1]

6. *Septastrea marylandica* (Conrad).
   Colony, X $\frac{1}{2}$. Tertiary age.[2]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EXPLANATION OF PLATE 5

Corals

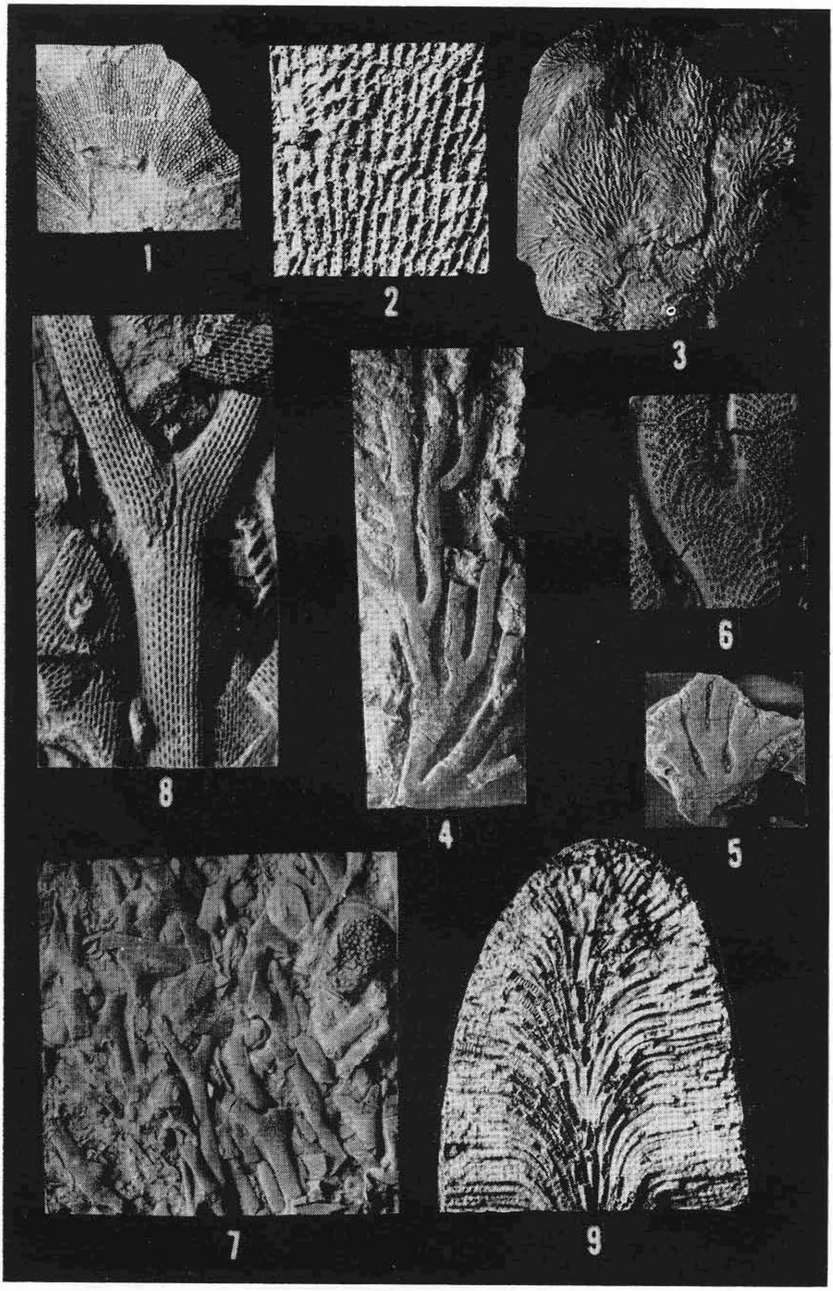
Figure

1–3. *Pleurodictyum lenticulare* (Hall).
1, calycinal view; 2, lateral view; 3, basal view; X 1. Devonian age.[1]

4. *Syringopora virginica* Butts.
Colony, X 1. Mississippian age.[1]

5–10. *Streptelasma stricturn* Hall.
5, 7–10, X 1; 6, same as 5, X 2. Devonian age.

11. *Favosites helderbergiae* Hall.
Colony, X 1. Devonian age.[1]



EXPLANATION OF PLATE 6

Bryozoans

Figure

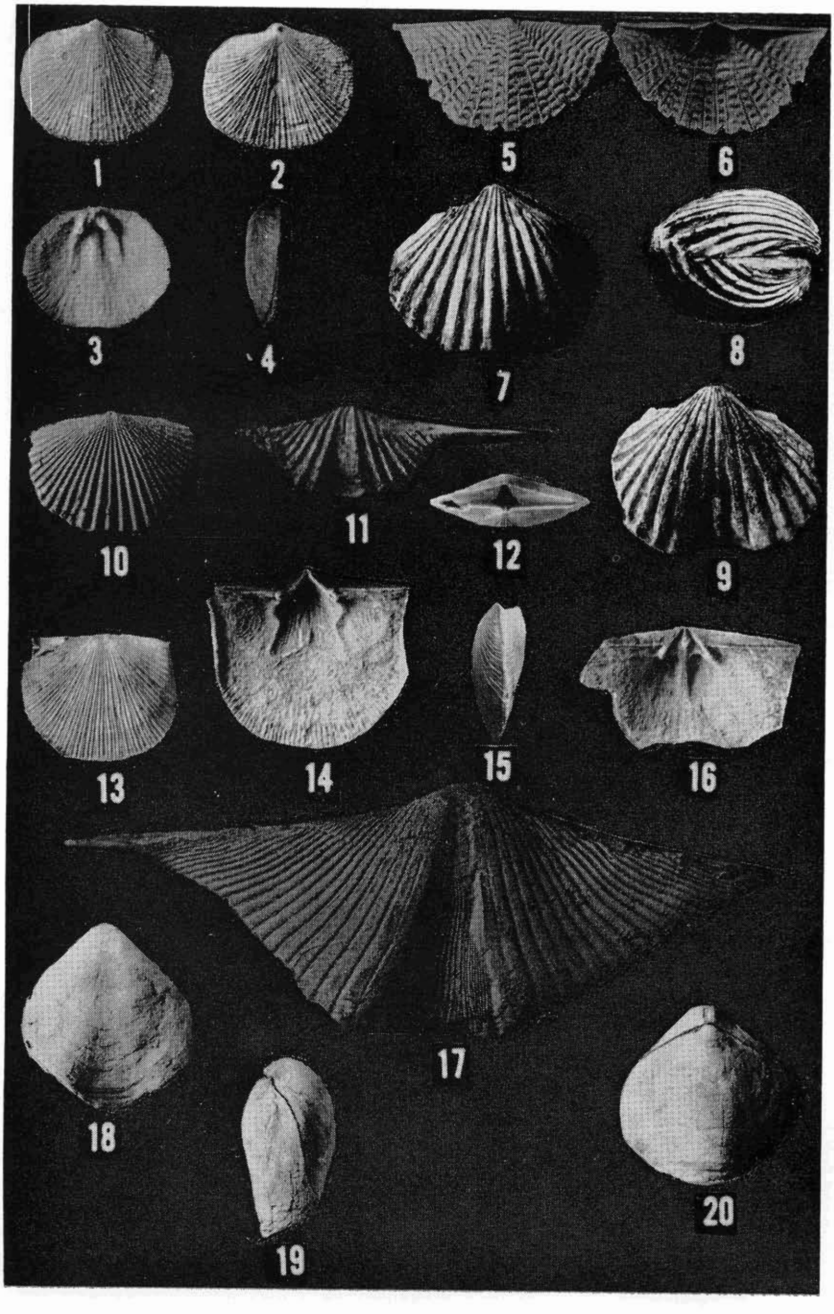
1, 2. *Fenestrellina serratula* (Ulrich).
1, external mold of the celluliferous surface in shale, X $1\frac{1}{4}$; 2, impression of part of 1, X $4\frac{1}{4}$. Mississippian age.[1]

3. *Chasmatopora* sp.
Specimen showing branching characteristics, X 1. Ordovician age.[1]

4–6. *Graptodictya* sp.
4 and 5, two specimens showing parallel branching and U-shaped bifurcation, X 1; 6, enlargement of 5, X 4. Ordovician age.[1]

7, 8. *Rhinidictya nicholsoni* Ulrich.
7, slab with several specimens, X 1; 8, central specimen of 7, X 4. Ordovician age.[1]

9. *Amplexopora cingulata* Ulrich.
Natural longitudinal section through a branch, X 4. Ordovician age.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EXPLANATION OF PLATE 7

Brachiopods

Figure

1–4. *Platyorthis planoconvexa* (Hall).
1, pedicle valve; 2, brachial valve; 3, interior of brachial valve; 4, profile view; X 1. Devonian age.[1]

5, 6. *Ptychoglyptus virginiensis* Willard.
15, pedicle valve; 16, interior of a pedicle valve; X 2. Ordovician age.[1]

7–9. *Orthorhynchula linneyi* (James).
Brachial, profile, and pedicle views of a specimen, X 1. Ordovician age.[1]

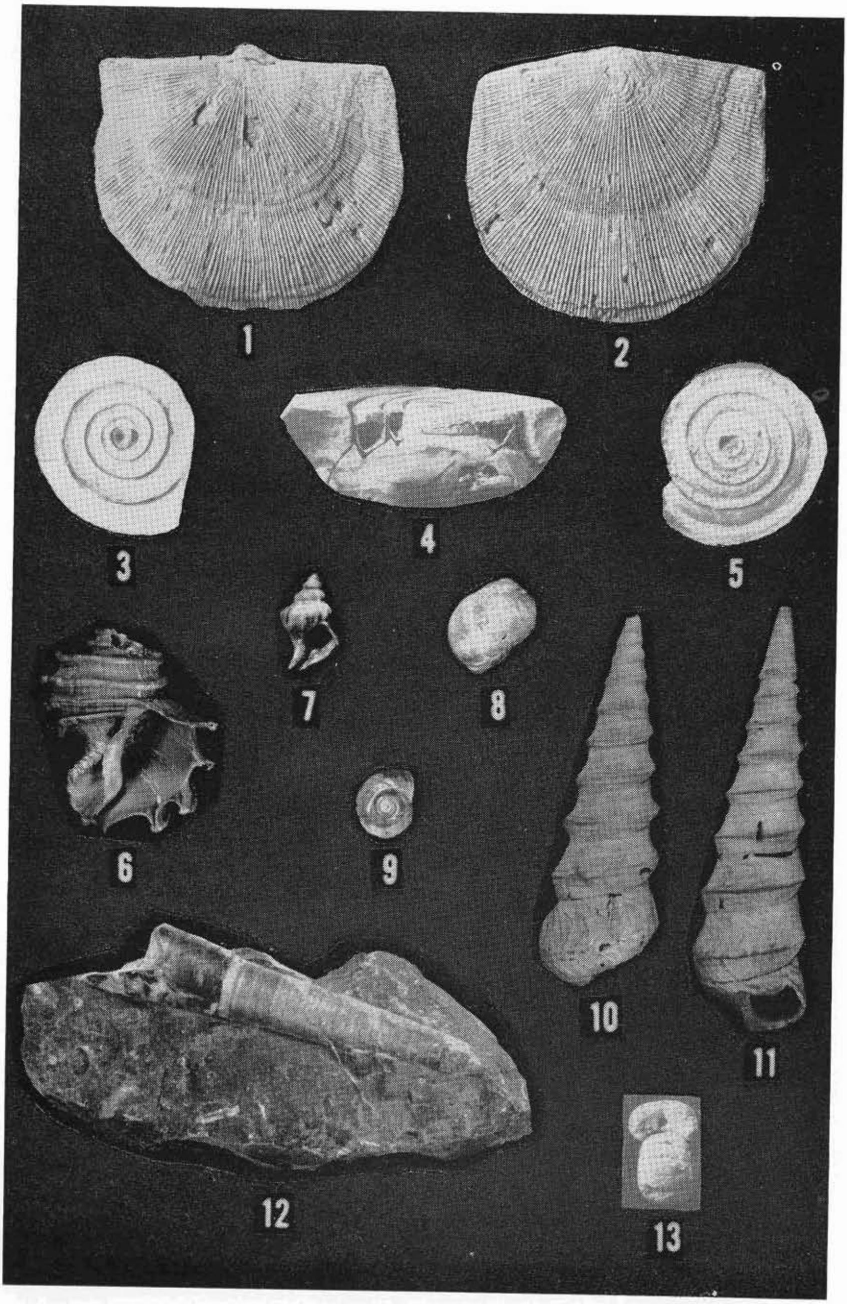
10. *Dinorthis ataroides* Willard.
Pedicle valve, X 1. Ordovician age.[1]

11. *Mucrospirifer mucronatus* (Conrad).
Internal mold of a pedicle valve, X 1. Devonian age.[1]

12–16. *Multicostella platys* (Billings).
12, posterior view; 13, pedicle valve; 14, interior of a pedicle valve; 15, profile view; 16, interior of a brachial valve; X 1. Ordovician age.[1]

17. "*Spirifer*" *mesistrialis* Hall.
Cast of an external mold of a pedicle valve, X 1. Devonian age.[1]

18–20. *Composita subquadrata* (Hall).
18, pedicle view; 19, profile view; 20, brachial valve; X 1¼. Mississippian age.[1]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EXPLANATION OF PLATE 8

Brachiopods

Figure

1, 2. *Schellwienella woolworthana* (Hall).
1, brachial valve; 2, pedicle valve; X 1. Devonian age.[1]

Gastropods

3–5. *Lecanospira compacta* (Salter).
1, internal mold, umbilical view; 2, natural section showing shape of whorls; 3, internal mold of depressed spire of 1; X 1. Ordovician age.[1]

6. *Ecphora quadricostata* Say.
Complete specimen, X ½. Tertiary age.[2]

7. *Strepsidura subscalarina*
Complete specimen, X ½. Tertiary age.[2]

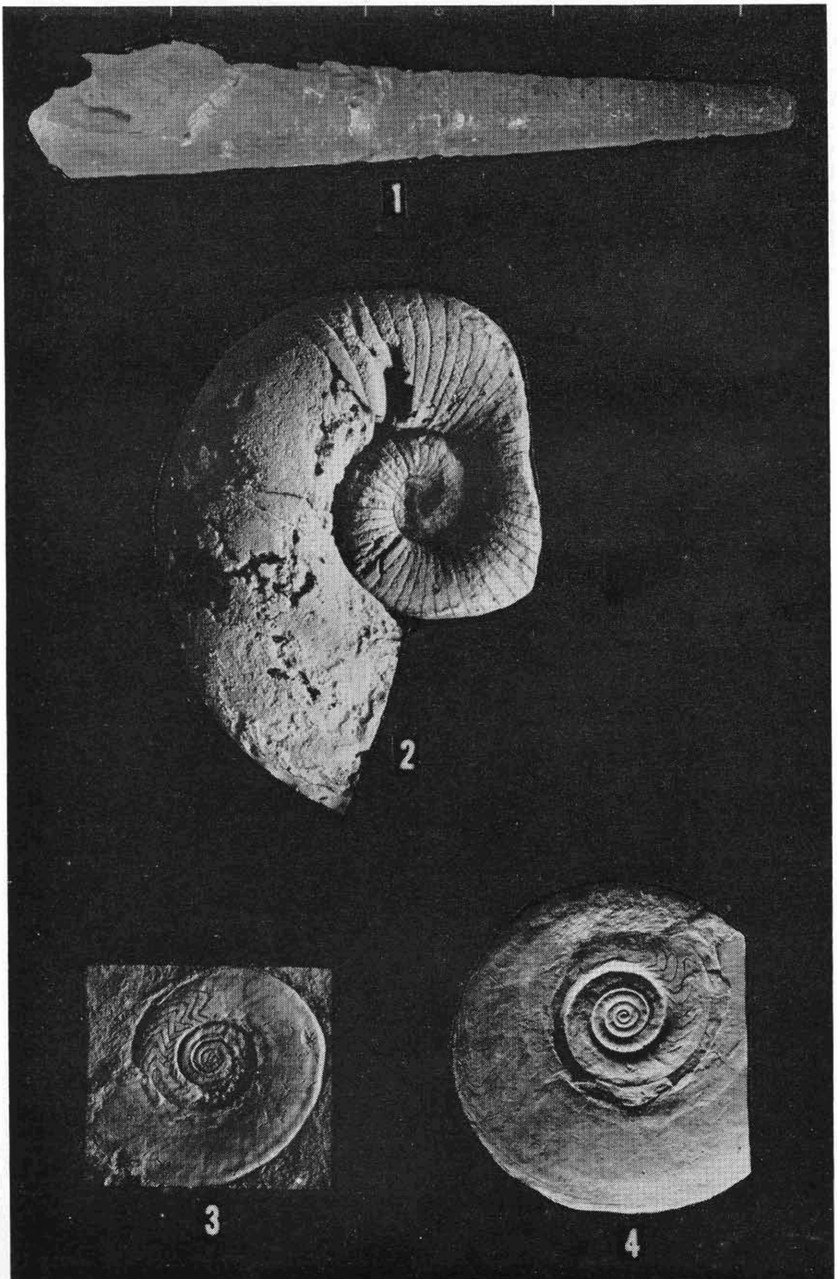
8, 9. *Lunatia marylandica*
8, complete specimen; 9, top view of 8; X ½. Tertiary age.[2]

10, 11. *Turritella mortoni* Conrad.
Two complete specimens, X ½. Tertiary age.[2]

Nautiloids

12. *Orthoceras* sp.
X ½. Ordovician age.

13. *Tarphyceras* sp.
Inner whorls showing shape of whorls and position of siphuncle, X ¾. Ordovician age.[1]



Explanation of Plate 9

Nautiloids

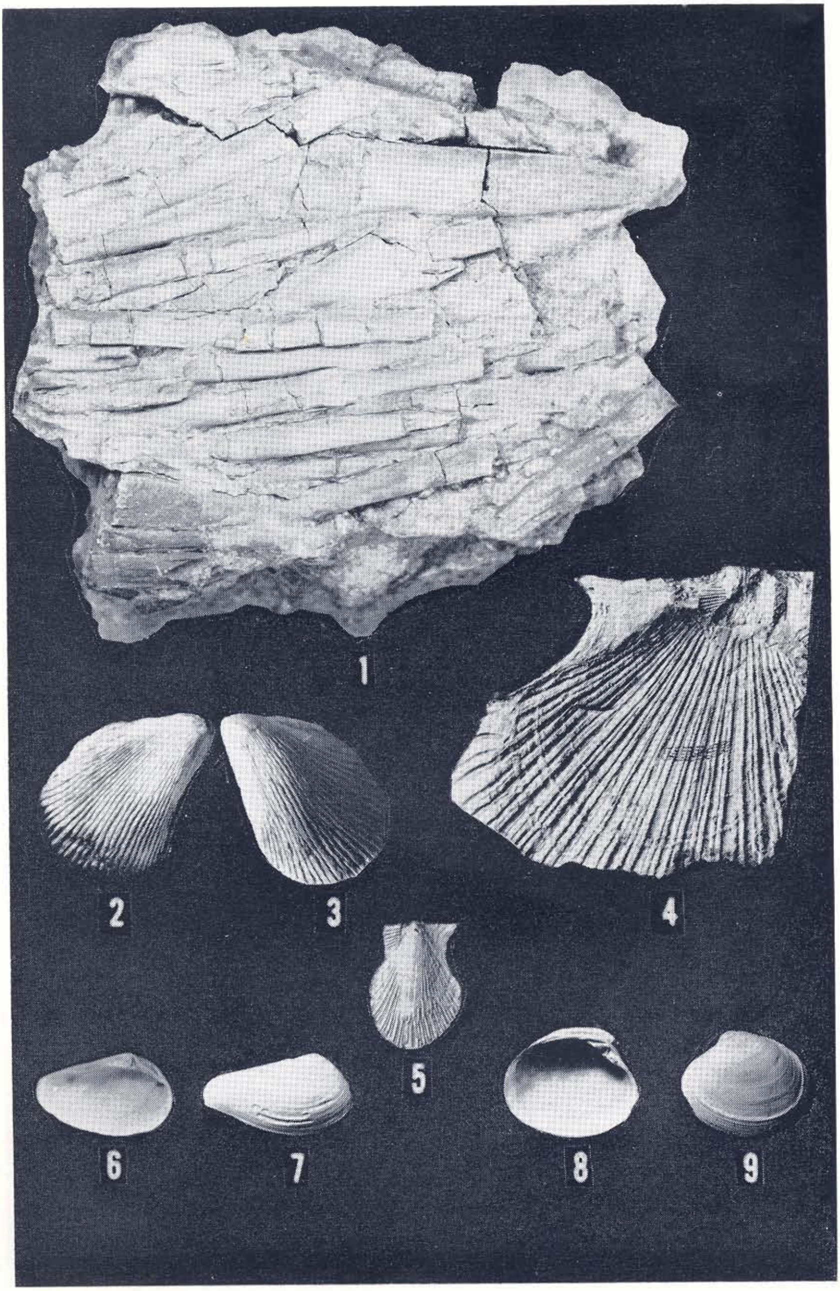
Figure

1. *Orthoceras* sp.
   X $\frac{1}{3}$. Ordovician age.

2. *Campbelloceras virginianum* (Hyatt).
   Internal mold in chert, X $\frac{3}{4}$. Ordovician age.[1]

Ammonites

3, 4. *Probeloceras lutheri* Clarke.
   Internal molds showing the zigzag sutures of the septae, X 1. Devonian age.[1]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EXPLANATION OF PLATE 10

Belemnoids

Figure

1. Belemnoids
X 1/3. Tertiary age.

Pelecypods

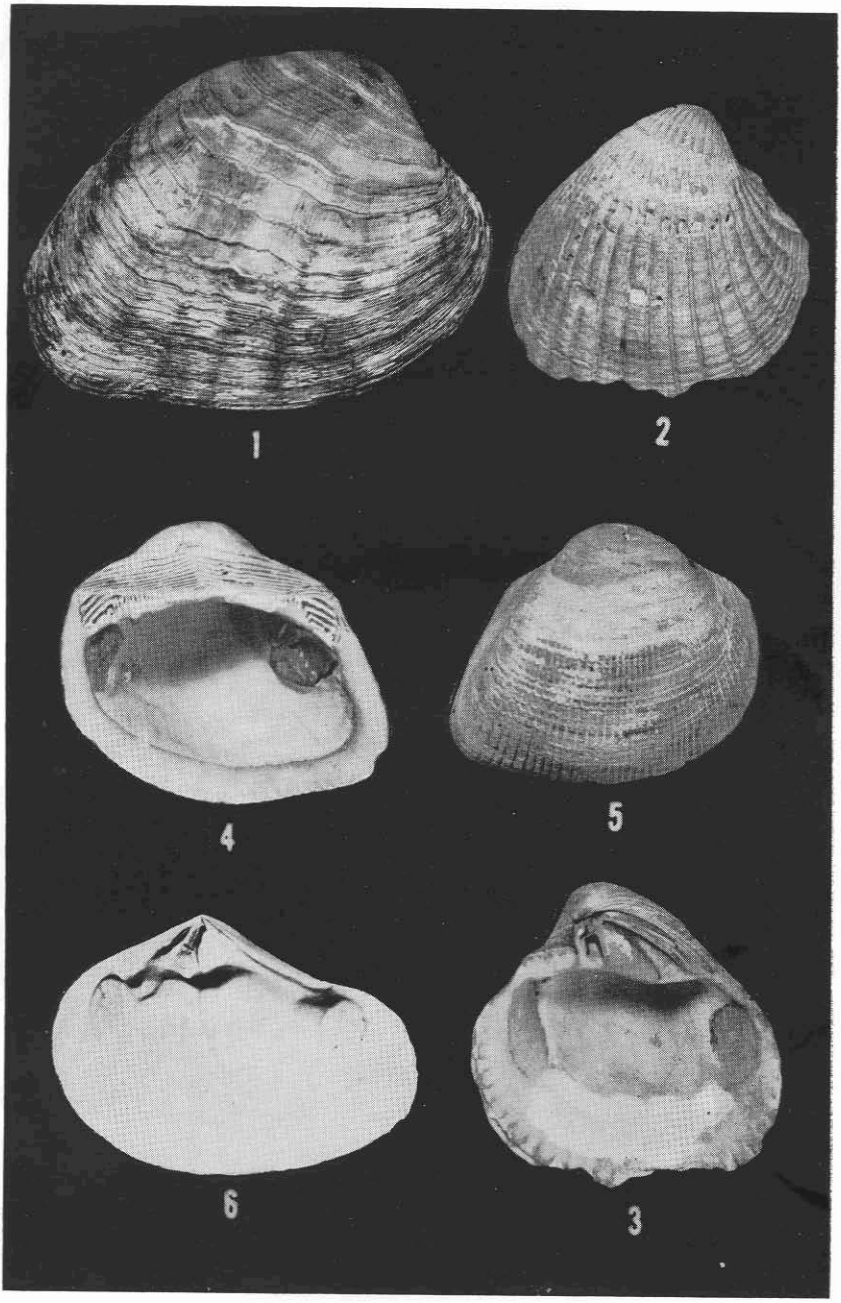
2, 3. *Byssonychia radiata* (Hall).
Right and left valves of a whole specimen; X 3/4. Ordovician age.[1]

4. *Lyriopecten interradiatus* Hall.
External mold of a left valve, X 1. Devonian age.[1]

5. *Aviculopecten* sp.
Left valve, X 1. Mississippian age.[1]

6, 7. *Crassatellites alaeformis*
6, interior of a left valve; 7, exterior of a right valve; X 1/2. Tertiary age.[2]

8, 9. *Meretrix ovata* var. *pyga*.
8, interior of a left valve; 9, exterior of a left valve; X 1/2. Tertiary age.[2]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EXPLANATION OF PLATE 11

Pelecypods[2]

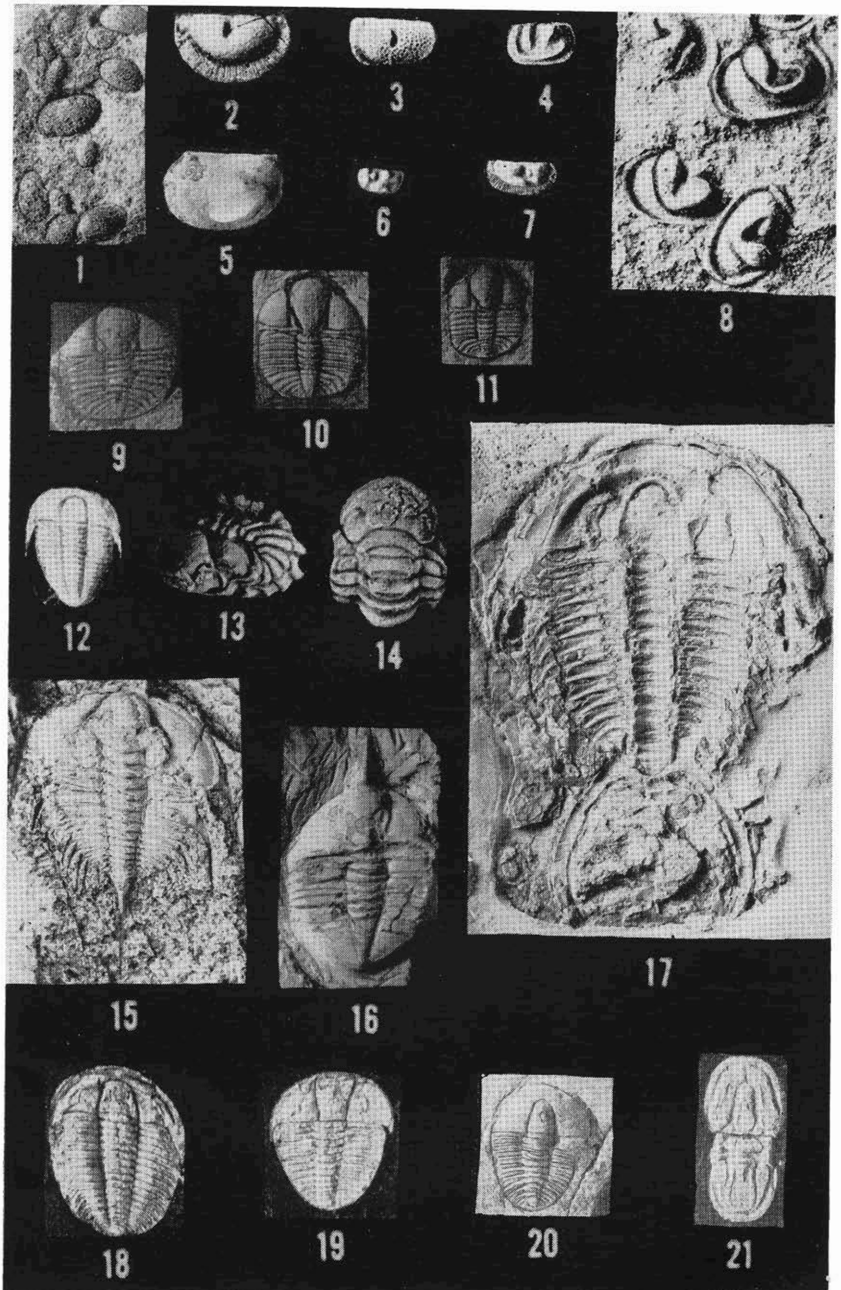
Figure

1. *Mercenaria tridacnoides* (Lamark).
   Exterior of a right valve, X $\frac{1}{3}$. Tertiary age.

2, 3. *Venericardia planicosta* Lamark.
   2, exterior of a right valve; 3, interior of a right valve; X $\frac{1}{2}$. Tertiary age.

4, 5. *Cucullaea gigantea* Conrad.
   4, interior of a right valve; 5, exterior of a right valve; X $\frac{1}{2}$. Tertiary age.

6. *Crassatellites undulatus* Say.
   Interior of a right valve, X $\frac{1}{2}$. Tertiary age.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Explanation of Plate 12

Figure

Ostracodes

1. *Leperditia elongata* var. *willsensis* Ulrich and Bassler.
   Slab with internal mold of both valves, X 1. Silurian age.[1]

2, 3. *Eurychilina reticulata* Ulrich.
   Two right valves, X 4. Ordovician age.[1]

4. *Drepanella crassinoda* Ulrich.
   Left valve, X 4. Ordovician age.[1]

5. *Isochilina armata* (Walcott).
   Right valve, X 4. Ordovician age.[1]

6, 7. *Hollina armata* (Ulrich).
   6, left valve; 7, right valve; X 4. Devonian age.[1]

8. *Mastigobolbina typus* Ulrich and Bassler.
   Wax impressions of external molds, X 4. Silurian age.[1]

Trilobites

9–11. *Ampyxina scarabeus* Butts.
   Three internal molds, X 1. Ordovician age.[1]

12. *Ptychoparella buttsi* Resser.
   Internal mold, X 2. Cambrian age.[1]

13, 14. *Sphaerexochus* sp.
   13, side view of enrolled specimen, 14, dorsal view of enrolled specimen, X 3. Ordovician age.

15. *Olenellus buttsi* Resser.
   Internal mold, X 1. Cambrian age.[1]

16. *Ampyx americanus* Safford and Vogdes.
   Internal mold, X 1. Ordovician age.[1]

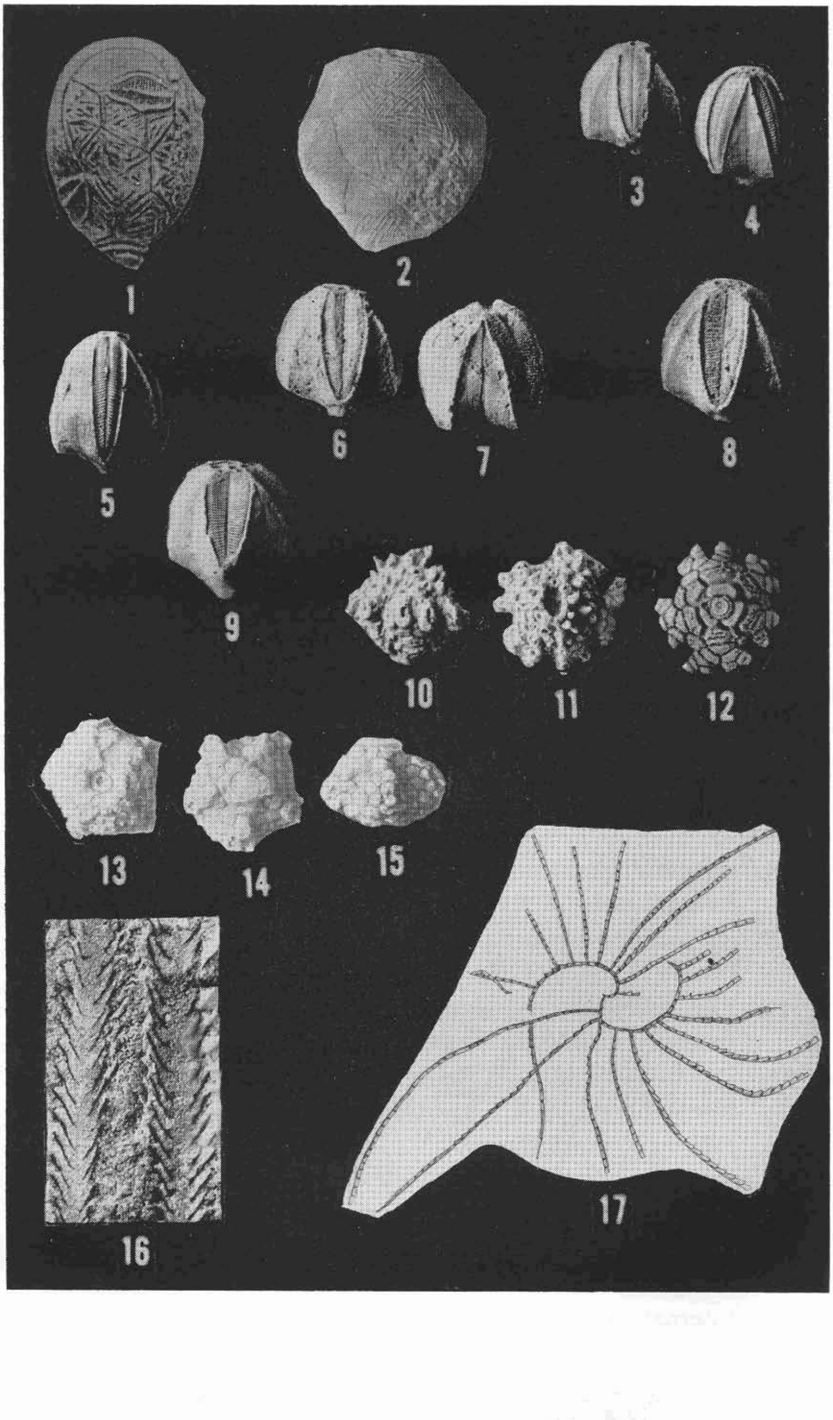
17. *Tricrepicephalus cedarensis* Resser.
   External mold, X 1. Cambrian age.[1]

18. *Ptychoparella michaeli* Resser.
   Internal mold, X 2. Cambrian age.[1]

19. *Poliella virginica* Resser.
   Internal mold, X 2. Cambrian age.[1]

20. *Norwoodella saffordi* (Walcott).
   Internal mold, X 1. Cambrian age.[1]

21. *Proagnostus bulbus* Butts.
   Internal mold, X 4. Cambrian age.[1]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Explanation of Plate 13

Cystoids[1]

Figure

1. *Lepocrinites manlius* Schuchert.
Lateral view, X 1. Devonian age.

2. *Echinosphaerites* sp.
Lateral view, X 1. Ordovician age.

Blastoids[1]

3, 4. *Pentremites planus* Ulrich.
Complete specimens, X 1¼. Mississippian age.

5. *Pentremites biconvexus* Ulrich.
Complete specimen, X 1¼. Mississippian age.

6–8. *Pentremites "godoni"* Ulrich.
Complete specimens showing depressed ambulacral areas, X 1¼. Mississippian age.

9. *Pentremites canalis* Ulrich
Complete specimen, X 1¼. Mississippian age.

Crinoids[1]

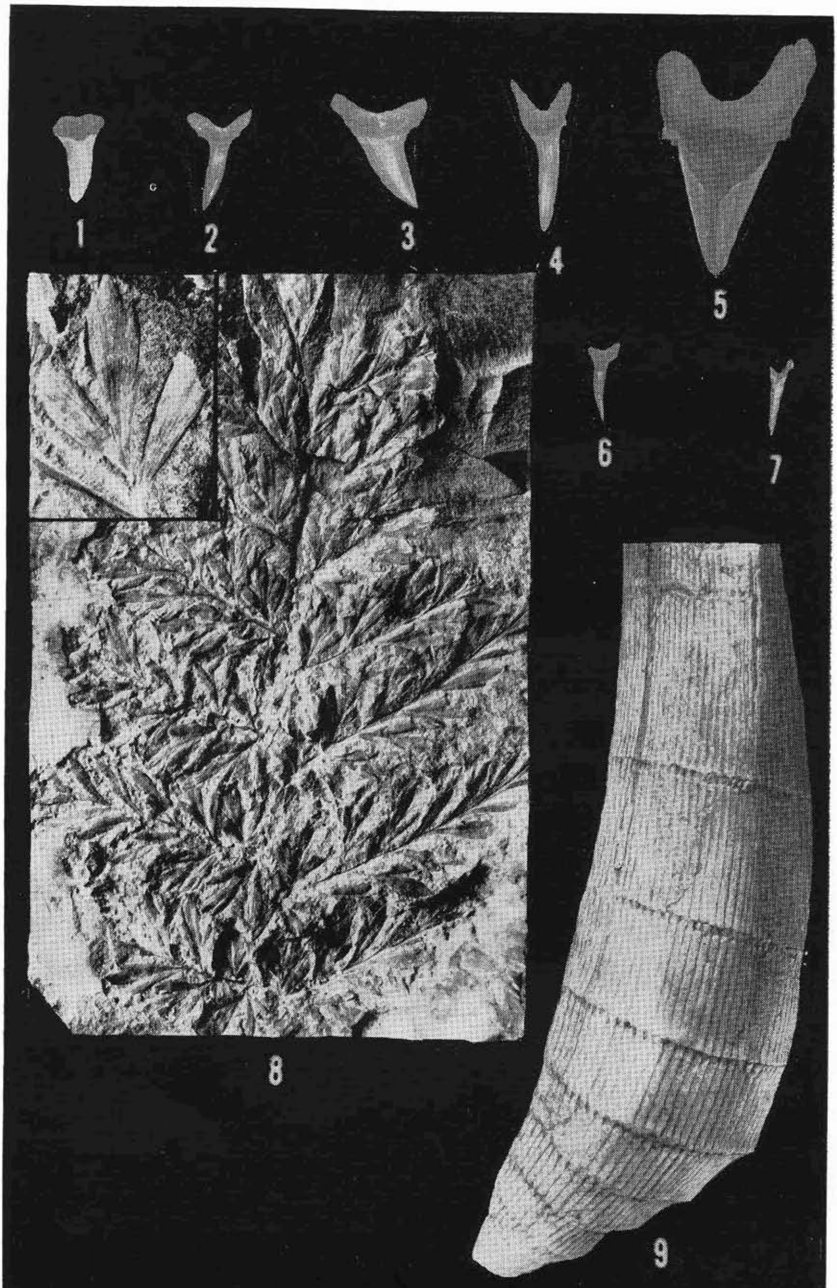
10–12. *Globocrinus unionensis* (Worthen).
Lateral, dorsal, and basal views, X 1. Mississippian age.

13–15. *Diabolocrinus perplexus* Wachsmuth and Springer.
Dorsal, basal, and lateral views, X 1. Ordovician age.

Graptolites[1]

16. *Diplograptus amplexicaulis* (Hall).
Enlargement of two specimens, X 4. Ordovician age.

17. *Nemagraptus gracilis* (Hall).
Camera lucida drawing by R. Ruedemann. Ordovician age.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Explanation of Plate 14

Vertebrates

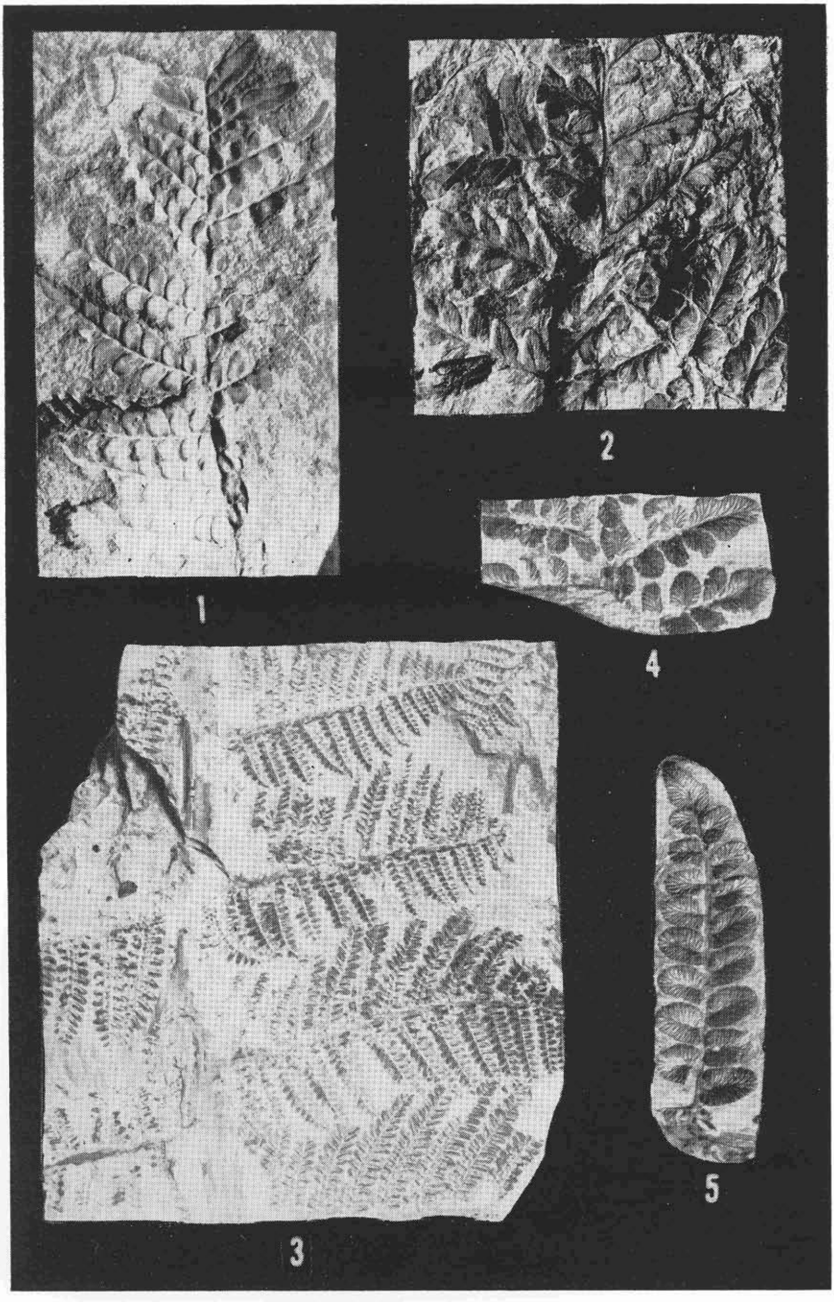
Figure

1–7. Shark teeth.
X $\frac{3}{4}$. Tertiary age.

Plants

8. *Triphyllopteris lescuriana* (Meek).
Impression of a frond, X $\frac{1}{3}$; inset in upper left hand corner of a trilobate punule, X 2. Mississippian age.[1]

9. *Calamites suckowi* Brongniart.
Internal mold of a hollow stem, X $\frac{3}{4}$. Mississippian-Pennsylvanian age.[1]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EXPLANATION OF PLATE 15

Plants[1]

Figure

1. *Neuropteris pocahontas* White.
   Impression of part of a frond, X 3/4. Pennsylvanian age.

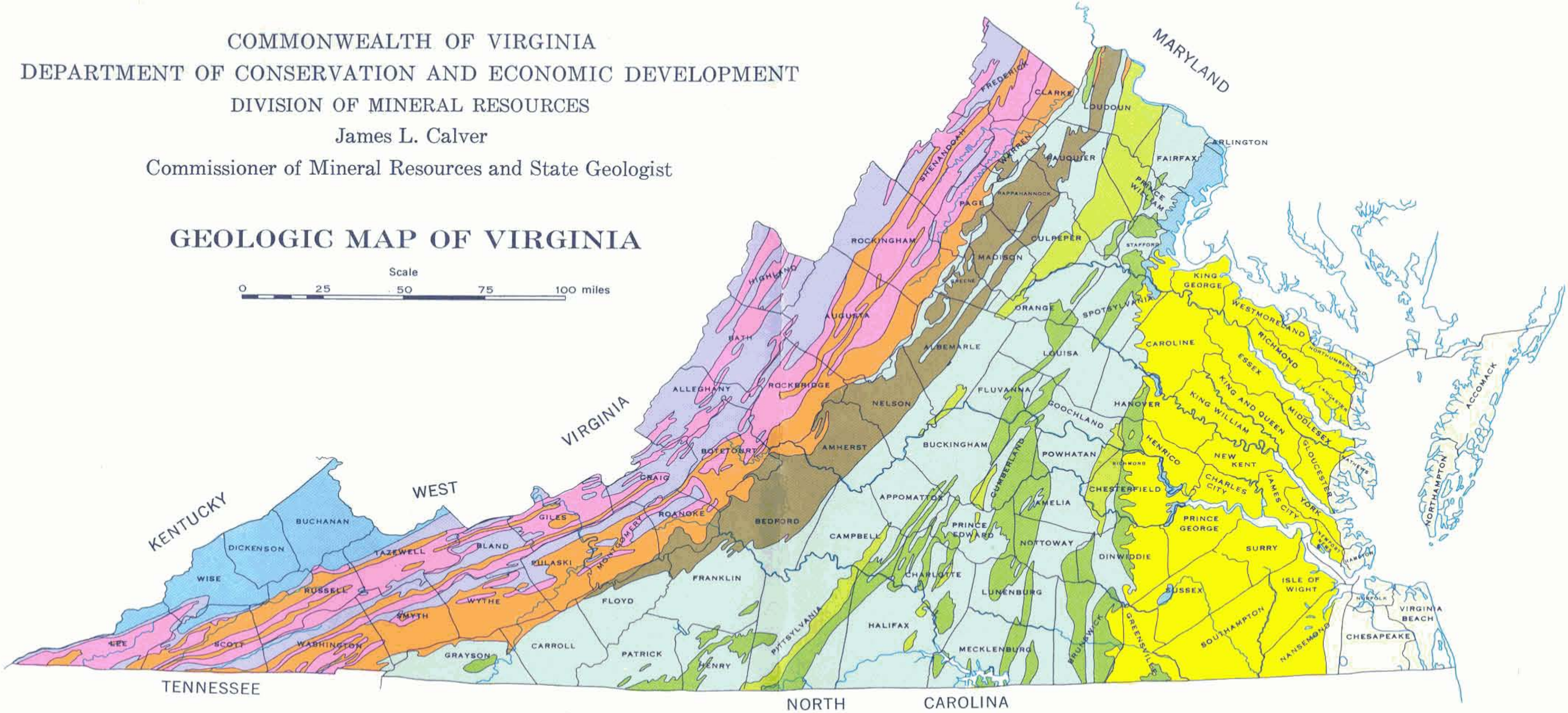
2. *Mariopteris pottsvillea* White.
   Impression of part of a frond, X 3/4. Pennsylvanian age.

3–5. *Neuropteris smithii* Lesquereux.
   3, part of a slab with large, well-preserved portion of a frond, X 1/4; 4, enlargement showing nervation of the pinnules, X 1 1/2; 5, part of a slab with an unusually large, well-preserved portion of a frond, X 1/4. Pennsylvanian age.

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES

James L. Calver
Commissioner of Mineral Resources and State Geologist

GEOLOGIC MAP OF VIRGINIA



CENOZOIC

QUATERNARY
(0-1 million years) Sand and gravel.
Sand and gravel.

TERTIARY
(1-70 million years) Loose or partly indurated sand, clay, marl, and diatomaceous earth.
Sand, clay, marl, and diatomaceous earth.

MESOZOIC

CRETACEOUS
(70-135 million years) Partly indurated sand, clay, and sandstone.
Sand and clay.

TRIASSIC
(180-225 million years) Red and gray shales and sandstones intruded by diabase; some thin coal layers.
Crushed stone, shale, and lightweight aggregate.

PALEOZOIC

PENNSYLVANIAN
(270-310 million years) Sandstone, shale, and coal.
Sand, coal, coke, lightweight aggregate, and natural gas.

MISSISSIPPIAN-DEVONIAN
(310-400 million years) Sandstone, shale, limestone, gypsum, and coal.
Coal, coke, silica sand, gypsum, shale, cement, salt brine, and natural gas.

SILURIAN-ORDOVICIAN
(400-500 million years) Limestone, dolomite, shale, and sandstone.
Lime, crushed stone, cement, shale, and petroleum.

CAMBRIAN
(500-600 million years) Dolomite, limestone, shale, and sandstone.
Crushed stone, sand, zinc, lead, and shale.

PRECAMBRIAN

VIRGINIA BLUE RIDGE COMPLEX
(Older than 600 million years) Granite and gneiss.
Crushed stone

ROCKS OF UNCERTAIN AGE

GRANITE and GNEISS
Granite, granodiorite, augen-gneiss, granite gneiss.
Crushed stone

METAMORPHIC ROCKS and IGNEOUS INTRUSIVES
Schist, slate, phyllite, quartzite, marble, metamorphosed arkose and conglomerate; greenstone, diorite, and gabbro.
Crushed stone, soapstone, anorthosite, slate, dimension stone, kyanite, feldspar, aplite, and titanium minerals.

Williams & Heintz Map Corporation, Washington 27, D.C.